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Performance Evaluation of Solid State Digester for Biogas Production using Biologically Pretreated Straw

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Abstract

The present paper reports biogas production from biologically pretreated paddy straw in a solid state digester made of HDPE plastic (124litre capacity). The trial was conducted with a mixture of 10 kg pretreated paddy straw, 20 kg cattle dung slurry, 20 kg cattle dung and 20 litre water. The chemical and proximate analysis of the feed was done and biogas production profile was studied over a period of one month. Parallel trial was also conducted with untreated paddy straw. The result indicated that 253.89 litre biogas/kg pretreated paddy straw was produced, which is 39.3% higher than the untreated paddy straw.

Highlights

- Fabricated digester worked well for biogas generation from untreatedas well as pretreated paddy straw.
- 39.3% enhancement in biogas production was observed in case of pretreated straw.

Keywords: Solid State Digester, Biogas, Paddy Straw, *Pleurotus florida*

One of the most abundant lignocellulosic wastes on earth is paddy straw. More than 200 million tons of paddy straw is estimated to be produced annually. About 70% of paddy straw is burnt in the fields which causes lung and respiratory diseases and adversely affect public health (Wang and Christopher, 2003). Furthermore, repeated burning of paddy straw also results in soil erosion. Thus, an alternative to utilize paddy straw is to use it as a feedstock for biogas production.

Though, biogas can be produced from paddy straw by anaerobic fermentation using cattle dung slurry as a source of inoculum. But, very few attempts have been made to investigate the potential of paddy straw as sole feedstock to produce biogas (Borjesson and Mattiasson, 2007). The barrier to which is the structure of paddy straw which has evolved to resist degradation due to crosslinking between the polysaccharides (cellulose and hemicellulose) and the lignin via ester/ether linkages (Yan and Shuya 2006). Efforts are being made worldwide to increase paddy straw digestibility by chemical, physical and biological means (Mosier *et al.*, 2005; Taherzadeh and Karimi, 2008; Hu *et al.*, 2008; Hendriks and Zeeman, 2009; Alvira *et al.*, 2010).

Biogas is composed of CH_4 (55-65%), CO_2 (30-45%), H_2 (1-5%), N_2 (0.5-2.0%), H_2S (0.1-0.5%), CO (0-0.3%) and traces of water vapors (Pauss *et al.*, 1987). The key to this process is that the H_2 produced by the acetogenic bacteria is removed by the methanogenic bacteria, which allows otherwise thermodynamically unfavourable metabolism of higher organic acids and alcohol to acetic acid and H_2 (Belaich *et al.*, 1990). Keeping in view the importance of paddy straw for energy and power generation along with combating the environmental pollution, the current study was carried out to biologically pretreat the paddy straw with a basidiomycete *Pleurotus florida* and to evaluate its performance in a prefabricated digester of 124 litre capacity.

Materials and Methods

Procurement of the materials: Paddy straw was procured from the Research Field of Punjab Agricultural University, Ludhiana. The paddy straw was chopped to 3-5 cm. Cattle dung was procured from the dairy farm of Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana and was used as inducer for biogas production from paddy straw. Digested cattle dung slurry was procured from a working biogas plant in field laboratory of School of Energy Studies for Agriculture, Punjab Agricultural University, Ludhiana and was used as inoculum for biogas production.

Pretreatment of paddy straw: Paddy straw was pretreated with *Pleurotus florida* commonly known as Dhingri. For pretreatment studies, wheat grain spawn of *Pleurotus florida* was prepared. To prepare spawn, wheat grains were washed and boiled for 20-30 minutes. The excess water was drained off. The grains were then mixed with 2% $CaSO_4$ and 4% $CaCO_3$. The grains were dispensed into empty glucose bottles (250 g/bottle). The bottles were plugged and autoclaved for 90 minutes. After cooling, the bottles were inoculated with 15 days old culture of *Pleurotus florida* and incubated at 27 ± 2^0C. The mycelium impregnated grains were used to inoculate paddy straw at the rate of 10% w/w ratio. After proper mixing, paddy straw was incubated at 27 ± 2^0C for 30 days. After the completion of required incubation, pretreated paddy straw was used to determine change in paddy straw composition *i.e.* cellulose, hemi-cellulose and lignin as well as biogas production.

Biogas production from paddy straw: Biogas production experiments were carried out in a cylindrical container 124 litre capacity made up of HDPE plastic (Fig. 1) following single phase digestion (Gupta *et.al.*, 2012).The mixture fed into the digester was 10 kg pretreated paddy straw +20 kg cattle dung + 20 kg digested cattle dung slurry + 20 litre water. The mixture was initially analyzed for pH, total solids, volatile solids, cellulose, hemi-cellulose, lignin and silica by AOAC Methods (AOAC, 2000). The biogas produced from paddy straw mixture was collected in gas holder which was measured by water displacement method. Parallel experiment was also conducted with untreated paddy straw mixture as well as cattle dung+slurry mixture. Biogas production experiment was conducted in May-June 2012 and during that period, maximum ambient temperature ranged between 35-46^{o}C and minimum ambient temperature ranged between 23-31^{o}C.

Statistical Analysis: Standard error (S.E) was calculated for all the experiments done in triplicate.

Fig. 1: Two sets of biogas digesters (124 litre capacity) along with displacement drums

Results and Discussion

Proximate and Chemical Analysis of paddy straw

Biologically pretreated paddy straw (*Pleurotus florida* for 30 days) was analyzed for change in chemical and proximate composition. Results from Table 1 indicate that pH of untreated paddy straw was 8.2 where as it decreased to 7.6 in case of biologically pretreated straw. A significant increase of 13.6% in cellulose content was observed in case of biologically pretreated paddy straw (i.e. 41.8%) as compared to the control 36.8%. This might be the result of consumption of lignin by the fungus thereby releasing free cellulose. Hemi-cellulose decreased significantly by 24.8% in case of biologically treated paddy straw as compared to the control. Similarly, almost 45% reduction in lignin content was observed in case of biologically pretreated paddy straw as compared to control. This decrease in hemi-cellulose and lignin could be the result of consumption of these by the fungus for its growth as a carbon source during primary and secondary growth phases. Kahlon and Dass (1987) found *Pleurotus ostreatus* and *Sporotrichum pulverulentum* inoculated paddy straw to be more digestible with significant reduction in lignin due to utilization of cell wall constituents by the fungi. Borgmeyer and Crawford (1985) observed 25% delignification after 8 weeks of growth of *Streptomyces viridosporus* on corn.

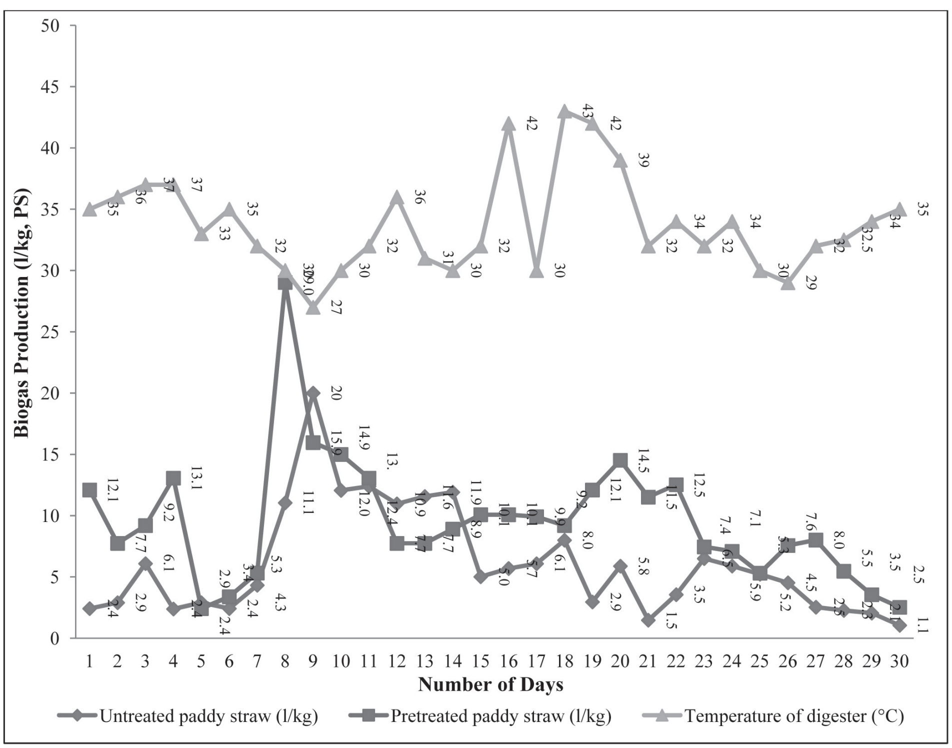
Table 1: Proximate and Chemical composition of *Pleurotus florida* pretreated paddy straw

Composition (%)	Untreated paddy straw	*P florida* pretreated paddy straw (30 days)
pH	8.2±0.09	7.6±0.07
Total Solids	93.7±0.29	93.1±0.27
Volatile Solids	85.1±0.35	83.1±0.41
Cellulose	36.8±0.21	41.8±0.25 (13.6 -)
Hemi-cellulose	16.5±0.19	12.4±0.23 (24.8 ¯)
Lignin	12.7±0.17	7.00±0.15 (44.9 ¯)
Silica	9.1±0.19	10.7±0.17 (17.6 -)

± values indicate Standard Error of triplicate data;
↑ depicts increase in composition w.r.t control, ¯depict decrease in composition w.r.t control

Biogas production profile

Fig. 2 shows the biogas production data from untreated paddy straw and pretreated paddy straw. A significant



⌗ Experiment performed in May – June, 2012
Maximum ambient temperature between 35-46°C
Minimum ambient temperature between 23-31°C

Fig. 2: Biogas production profile of untreated and pretreated paddy straw

variation in daily biogas production was observed over a period of one month. This variation might be due to the fluctuation digester's temperature or/and atmospheric temperature.

Table 2 shows the total biogas production from the paddy straw mixture. A total of 182.1 l biogas/kg PS was produced from untreated straw whereas 253.9 l biogas/kg PS was produced in case of biologically pretreated paddy straw showing an increase of 39.3% which is found to be the result of increased paddy straw digestibility of pretreated straw resulting from decreased lignin content.

Biological pretreatment not only provides a simple and inexpensive method of pretreatment but is also an environment friendly approach. Similar results were obtained by (Phutela *et al.*, 2012) who reported 15.2% enhancement in biogas production at laboratory scale.

Table 2: Biogas production from paddy straw mixture

Parameter	Untreated paddy straw (control)	Pretreated paddy straw
Total Solids of mixture (%)	25.7±0.52	25.3±0.57
Volatile Solids of mixture (%)	78.4±0.69	74.6±0.58
Biogas(l/kg PS*)	182.1±12.3	253.8±11.9 (39.3-)

*PS: Paddy straw; ± values indicate Standard Error of triplicate data

Conclusion

From above studies, it is concluded that the fabricated digester worked well for biogas generation from untreated as well as pretreated paddy straw. Also 39.3% enhancement in biogas production was observed in case of pretreated straw. This model can be used for construction and fabrication of bigger sized biogas plants. However, the daily fluctuation in atmospheric temperature is the main cause of concern which needs to be controlled for maximizing biogas production.

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